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In areas of light rainfall, soil moisture is apt to be the factor that most limits tree growth. To date, however, little thought has been given the problem in areas such as south Arkansas and north Louisiana, where rainfall averages 50 inches or more per year.

Seemingly, an average of nearly an inch of water per week should more than suffice for maximum growth of forest stands. The difficulty is that rainfall is not uniform throughout the year in this territory. Summer droughts from two to six or more weeks in length are fairly regular. Narrow growth rings and mortality of trees have raised the question of just how adequate the moisture supply is.

The seasonal trend of soil moisture in forests has received limited attention. Gaiser (2)[1/], working on three upland oak sites in southeastern Ohio, found that water available for plant growth dropped to a critical level by mid-summer. The water regime under a young pine plantation in South Carolina was studied by Hoover, Olson, and Greene (3). They reported that water was removed from a 60-inch depth at about the same rate as from the surface depths, even though roots were concentrated near the surface. Roots removed water down to the wilting point regardless of the depth or root concentration.

Boggess (1), in south Illinois, has shown strong correlation between tree growth and available soil moisture. Both pine and hardwood radial growth virtually ceased by the end of June, when soil moisture neared the wilting point. Intermittent summer showers failed to replenish moisture (in the root zone as a whole) enough for growth to continue.

1/ Underscored numbers in parentheses refer to Literature Cited, p. 14.

It would seem that soil moisture becomes limiting at just the season when other environmental factors are near optimum for good forest growth. There is a need for detailed moisture determinations during this period of limited water supply. The present study is concerned with the effects of various forest conditions on the summer depletion of soil moisture.

Study Areas and Methods

During the very dry summer of 1953, soil moisture was periodically measured under six different forest stand conditions in southeastern Arkansas. All of the areas studied were on the same soil type, a Leshe[2/] silt loam, on the Crossett Experimental Forest. Topography also was similar on all areas.

Soil and topographic descriptions

The Leshe soil series is developed on high terraces of old alluvium composed of sediment from the Permian redbeds and from the red and yellow soil zones. Topography is of the "upland flatwoods" type, with imperfect surface drainage. The micro-relief shows slopes up to 4 percent. The dark grey silt loam surface soil grades into a yellow silt loam subsoil at from 8 to 12 inches, with a mottled grey silt loam pan development at about 24 inches. Internal drainage is slow. Table 1 summarizes soil profile data for the study areas. Loblolly pine site index for Leshe soil on imperfectly drained sites is about 90 feet at age 50.

Table 1.--Physical properties[1/] of Leshe silt loam, for four depths

Soil depth (inches)	Composition			Bulk density	Moisture equivalent	Wilting point	Available water[2/]
	Sand	Silt	Clay				
	- - Percent - -				- - - Acre-inches[3/] - - -		
0- 6	21	66	13	1.37	1.6	0.4	1.2
6-12	20	63	17	1.47	1.7	.5	1.2
20-26	20	59	21	1.53	1.8	.6	1.2
42-48	20	59	21	1.64	2.0	.7	1.3

1/ Averages of the 6 study sites.
2/ Moisture equivalent minus wilting point.
3/ Per 6-inch layer.

2/ Series tentatively assigned, pending correlation.

Stand descriptions

Six different stands, on three separate areas, were studied. The three areas consist of an all-aged loblolly and shortleaf pine stand with a typical understory of hardwoods, a non-commercial all-aged hardwood type, and a relatively even-aged young hardwood type with commercial possibilities. Within the pine type two stand conditions were measured, the pine type itself and a clearcut bare area. The all-aged hardwood type furnished three stand conditions: an area that had received timber stand improvement in 1951, an identical area that received the same treatment in 1953, and an untreated area. The young hardwood type provided only the one condition of even-aged hardwood.

Table 2 summarizes stand data for the three areas.

Table 2.--Stand data per acre for the three study areas

Area type and species group	Stems	Average d.b.h.	Largest d.b.h.	Basal area
	Number	Inches	Inches	Sq. ft.
All-aged pine				
Pine	95	13.4	26	88
Hardwoods	50	6.2	8	13
Total	145			101
Cull hardwoods				
Pine	5	7.0	10	1
Hardwoods	150	9.3	16	70
Total	155			71
Young hardwoods				
Pine	0	...	...	...
Hardwoods	310	6.3	9	67

All-aged pine.--The Pine site is in an area typical of much of the managed pine forest in southeast Arkansas and northern Louisiana (fig. 1). The dominant trees range up to 26 inches d.b.h. The basal area is about 70 square feet per acre, and the board-foot volume is 5 to 8 M per acre. The understory hardwoods are chiefly sweetgum

Figure 1. --The all-aged loblolly-shortleaf pine area.

and southern red oak, of all sizes up to about 20 to 30 feet in height and 8 inches d.b.h. Other oaks, dogwood, hawthorn, and vaccinium species are also present.

During the winter of 1953, a 30- by 30-foot plot within the pine area was completely cleared of all vegetation. All overstory and larger understory trees within 50 feet of the plot center were also removed. Understory hardwoods on the plot were cut and the stumps chemically treated to prevent sprouting; the foliage of lesser vegetation was chemically sprayed. The resulting plot was completely bare of vegetation. The soil was exposed by removing the surface litter. This plot is called the <u>Bare</u> site.

<u>All-aged cull hardwoods.</u>--This stand is typical of much of the badly cutover upland pine-hardwood forest of the area (fig. 2). Most pine was removed at least 40 years ago and the small cull hardwoods that remained after logging grew into the present all-aged hardwood type, with a moderately developed hardwood understory. The principal species are southern red oak, post oak, and sweetgum, the largest of which have diameters up to 16 inches. A few scattered pine seedlings and saplings are also on the plots. About four large loblolly pine and shortleaf pine per acre occupy the area, but do not occur on the plots themselves.

Within the all-aged cull hardwoods area, three 50- by 50-foot plots were chosen for similarity of stand conditions. In 1951, one plot had been given a timber stand improvement treatment in which all hardwoods four inches d.b.h. and over were frilled and treated with a water emulsion of 2,4-D; the remaining stand consisted of a few small hardwoods and scattered pine. In 1953, a second plot was treated identically. The third plot was left as an untreated control. The three plots are called, respectively, <u>TSI 1951</u>, <u>TSI 1953</u>, and <u>Untreated Hardwood</u>. In contrast to the other two plots, the TSI 1951 plot had developed some scattered pine reproduction by the summer of 1953.

<u>Young even-aged hardwood.</u>--This area is being managed for the commercial production of upland hardwood sawlogs (fig. 3). The dominant stand varies from 30 to 35 years of age. The area is well stocked, and diameters range from 3 to 9 inches. Principal species are southern red oak and post oak. Understory hardwoods are present but not abundant.

Figure 2.--The cull hardwoods area.

Figure 3.--The young upland hardwoods area.

In this even-aged hardwood stand, a representative 50- by 50-foot plot was selected. This plot is called the Young Hardwood site.

Measurements

Soil moisture was measured on all six sites from May 20 to September 24, 1953. Moisture content was determined at four depths: 0-6 inches, 6-12 inches, 20-26 inches, and 42-48 inches. On the TSI 1953 and the Young Hardwood plots[3/], four randomly selected points were sampled gravimetrically at each depth at two-week intervals. On the other four sites fiberglas units were employed according to the method described by Reinhart (4), except that calibrations of the units were made on 18- by 18-foot areas. Fiberglas unit readings from the four depths were recorded daily.

Bulk density and wilting point determinations were replicated three to four times for each of the four depths at each site. Bulk density was measured with 71.0 c.c. undisturbed soil cores. Wilting point was determined at 15 atmospheres pressure on disturbed soil samples in a pressure-membrane cell.

Rainfall

Gross daily rainfall was recorded for the pine and the cull hardwoods areas. Rain gauges were placed in open areas not far from the study sites. Rainfall measured at the cull hardwoods area was considered applicable to the Young Hardwood site, three-fourths of a mile away.

Rainfall data are summarized in table 3. All of the May rain (9.50 inches for the hardwood areas and 10.06 for the pine) fell prior to May 20, when soil-moisture observations began. This excess of more than five inches during May, on top of normal winter and spring precipitation, was slow in draining off. On the other hand, only about 1.4 inches fell on either area from May 20 to July 20, and it came in seven separate showers. A severe drought was therefore felt during the latter part of June and the first 20 days of July. Both areas recorded about normal precipitation for August, although the first two weeks of this month were dry. September again showed severe drought conditions.

3/ C. X. Grano collected the data on these two sites.

Table 3.--Rainfall data for May through September, showing normals for the Crossett area and the 1953 record for two of the study areas

Month	Rainfall				
	Normal 1/	Cull hardwood area		All-aged pine area	
		Recorded 1953	Deviation from normal	Recorded 1953	Deviation from normal
	- - - - - - - - - - - -	- - - - -	Inches	- - - - -	- - - - - - - - - - - -
May	4.14	9.50	+5.36	10.06	+5.92
June	4.07	.93	-3.14	.65	-3.42
July	4.62	3.86	- .76	5.26	+ .64
August	3.21	2.62	- .59	2.91	- .30
September	2.39	.31	-2.08	.26	-2.13
Total	18.43	17.22	-1.21	19.14	+ .71

1/ From official records of U. S. Weather Bureau.

Analytical methods

Soil moisture observations were calculated in terms of inches of available water per 6-inch layer of soil for each of the four depths. Available water is taken as that field moisture content over and above the moisture content at wilting point.

Available water in the upper 48 inches of soil on each site was calculated as the sum of water available in the four 6-inch layers, plus an interpolated amount of water in the intervening layers.

Results and Discussion

The three forested sites showed similar trends of soil moisture depletion. Where vegetation was modified, however, the trend and degree of depletion were respectively modified.

TSI sites

Comparisons of soil moisture on the three sites of the cull hardwood area are presented in figures 4 and 5. Figure 4 shows the available water in the whole upper 48 inches of profile on the three sites. Soil water was probably adequate for growth throughout the summer on

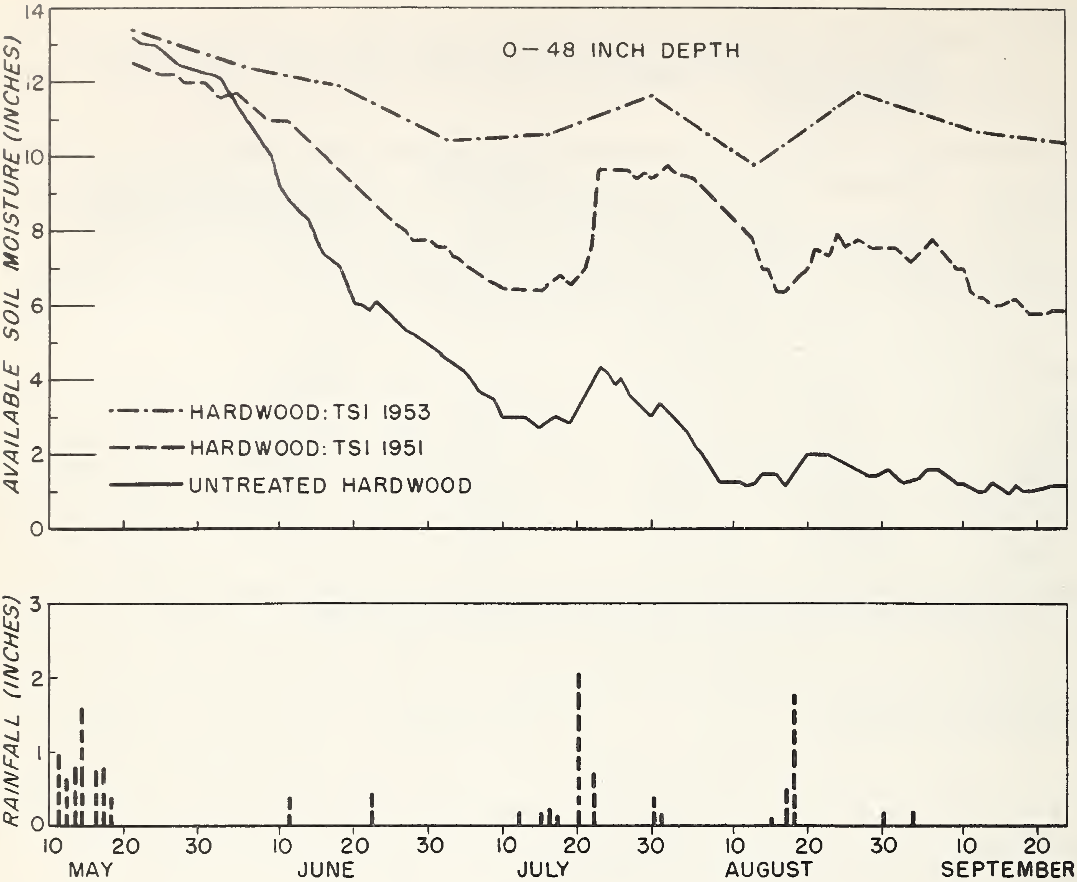

Figure 4. --Summer trends of soil moisture in the upper 48 inches of the TSI and Untreated Hardwood sites. 1953.

both TSI sites, whereas by the first of July soil water may have been critical on the Untreated site. This difference in available water was due, of course, to transpiration by the trees on the Untreated site.

The differences between the TSI 1951 and TSI 1953 sites are confined to the surface layers rather than the subsoil (fig. 5). Along with the pine seedlings a rather dense ground cover of herbaceous vegetation and blackberry vines (evidently an invasion after the 1951 treatment) removed water from the surface 18 inches of soil on the TSI 1951 site. Lesser vegetation had not had time to develop on the TSI 1953 site, and little water was removed. These results suggest that reproduction

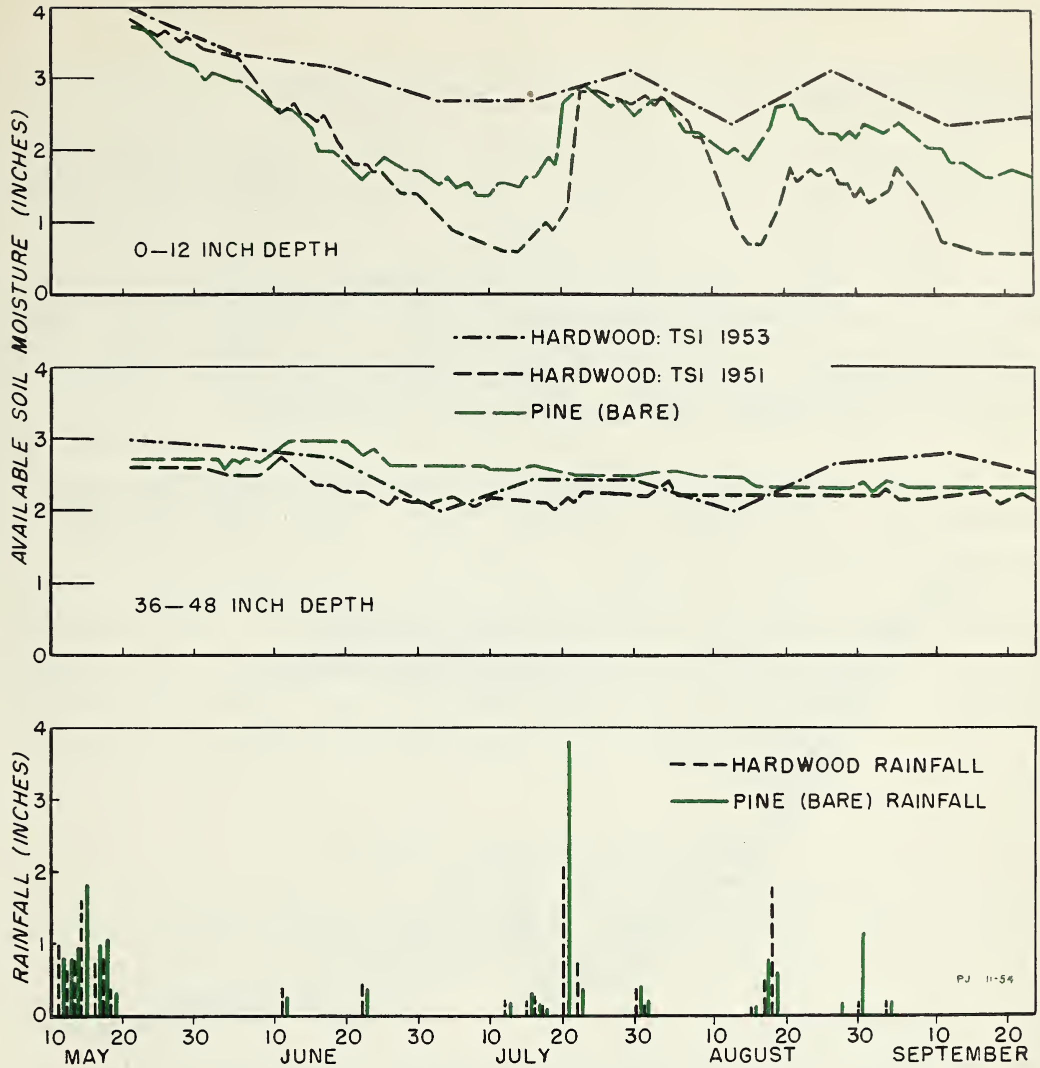

Figure 5. --Summer trends of soil moisture in the 0-12 inch depth and the 36-48 inch depth of the TSI and Bare sites. 1953.

established in the first year after timber stand improvement should grow better than similar regeneration during later years.

The summer rains of July and August did not appreciably increase the total water on the Untreated and TSI 1953 sites. The latter was already wet, and on the former the rains did not reach the 20-inch sampling depth.

Untreated Hardwood, Young Hardwood, and Pine sites

Results on the Untreated Hardwood, Young Hardwood, and Pine sites show that well-stocked forests, regardless of composition, rapidly deplete the soil of water during the summer. Transpiration in a few weeks reduces soil moisture to a point where growth undoubtedly is restricted. On all three sites, soil moisture dropped from saturation in late May to near the wilting point by late June. At the beginning of June the Leshe silt loam soil still had about 11 inches of available water stored in the surface 48 inches. Transpiration removed about 4 inches of this in only two weeks, and up to 7 inches in four weeks.

Figure 6 compares the all-aged Pine and the all-aged Untreated Hardwood sites. The moisture depletion curves for the entire profile

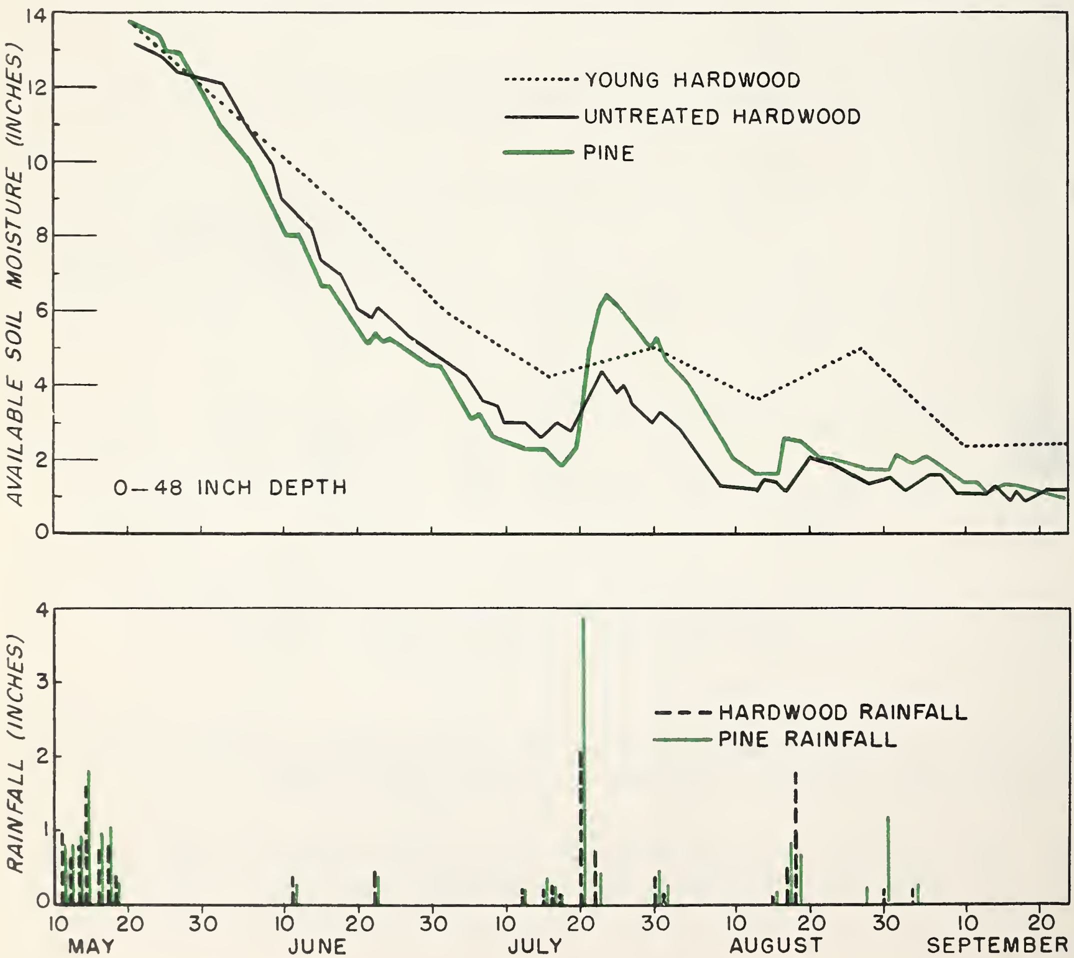

Figure 6. --Summer trends of soil moisture in the upper 48 inches of the Young Hardwood, Untreated Hardwood, and Pine sites. 1953.

are essentially identical, except for the influence of the rain of July 20. The additional rain on the Pine site wetted the soil to the 20- to 26-inch depth, whereas this depth was not affected on the Untreated Hardwood site. Prior to this rain, both sites were dry, the trees having used up most of the available water by early July.

The young even-aged hardwoods depleted the soil of water almost to the extent that the all-aged cull hardwoods did. Trees and shrubs on both sites removed most of the available water by early July (fig. 6), and there is little difference between the two areas. The additional inch of water that was apparently removed from the Untreated site may not be significant for the methods employed.

TSI 1953 and Bare sites

Although moisture was depleted rapidly on the untreated forest sites, it remained relatively high throughout the summer on the TSI 1953 and Bare sites. The TSI 1953 site consistently had the higher water content (fig. 5), undoubtedly because surface evaporation was reduced by the undisturbed litter and shade from the dead hardwoods. Again, the difference was confined to the surface 12 inches of soil.

Summary and Conclusions

During the summer of 1953, soil water depletion was measured under six different forest conditions in south Arkansas. Three forested sites were left undisturbed, while three others were variously treated to remove vegetation.

Where pine or hardwood stands with a stocking of 70 to 100 square feet of basal area were undisturbed, water was removed from the ground rapidly with the onset of hot dry weather. On plots where large cull hardwoods were deadened, and where all living vegetation was removed, soil water remained relatively high throughout the summer.

The summer was a dry one, and rainfall only moderately affected the total moisture on the undisturbed sites. Evapo-transpiration quickly depleted the soil of water added by these showers.

Soil water depletion was greater where all vegetation had been removed than where only culls had been deadened, but this difference was apparent only in the surface layers. Below the effective zone of evaporation on these sites, soil water remained at a rather constant high level.

The study indicates that very serious consideration should be given to methods of stand treatment which will both conserve moisture and permit the water supply to be used by the more desirable species. During the summer, droughts occur nearly every year throughout the western portion of the shortleaf-loblolly pine-hardwood type, and lack of soil moisture undoubtedly limits tree growth.

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